Misconceptions in Science

ITTECF – How pupils learn – standard 2 – promote good progress

Session aims

- Develop an understanding of what misconceptions and preconceptions are in science learning and why they matter for teaching.
- Explore key sources and examples of common misconceptions in biology, chemistry, and physics at KS3/KS4.
- Understand the impact of prior knowledge on pupils' conceptual development and science learning.
- Examine evidence-based strategies for identifying, addressing, and monitoring misconceptions through classroom dialogue, assessment, and targeted intervention.
- Reflect on the role of curriculum, teaching models, and classroom practice in either reinforcing or remedying misconceptions.
- Recognise the importance of ongoing conceptual change and metacognitive approaches for deep, durable science understanding.

Questions

1. Where do plants get their food from?
2. Plants carry out photosynthesis and animals carry our respiration. True or false?
3. What happens to a spoonful of salt when you put it into a beaker of water?
4. Heavy objects fall faster than lighter objects. True or false?
5. When you turn on a radiator the heat rises up and warms the room. True or false?
6. Why do blood vessels look blue through pale skin?
7. Where is the heart located?
8. Humans breathe in carbon dioxide and breathe out oxygen. True or false?
9. What are bubbles made of in soda drinks?

Key terms

Mistakes

- Definition: Mistakes are typically slips or lapses—caused by carelessness, distraction, or forgetting.
- Features: They are not rooted in a misunderstanding of the concept and are often corrected easily when pointed out ("I knew that!").

Errors

- Definition: Errors are inaccuracies resulting from a missing piece of knowledge, misunderstanding, incomplete connection, or a mistake carried forward.
- Features: Errors may need small interventions and are not always deeply embedded in conceptual frameworks. They might arise from hasty reasoning or lack of attention.

Key terms

Misconceptions

- Definition: Misconceptions are incorrect beliefs or ideas that are part of a learner's mental model or conceptual framework.
- Features:
  - They are deeply held and make sense to the learner, but are scientifically inaccurate.
  - They often arise from everyday experiences, prior teaching, or naive logical reasoning.
  - Addressing misconceptions requires targeted instructional interventions, not just correction or feedback.

Preconceptions

- Definition: Preconceptions are existing ideas, beliefs, or attitudes that learners bring to the classroom prior to formal instruction.
- Features:
  - They might be correct or incorrect.
  - They influence how new concepts are understood and linked.
  - If incorrect, preconceptions can evolve into misconceptions when not addressed effectively.

Addressing misconceptions in science

- Student beliefs matter: Learners arrive with beliefs and prior knowledge shaped by experiences and previous teaching.
- Acknowledge and explore: Prior learning - whether correct, incomplete, or a misconception - impacts new understanding and needs to be surfaced in lessons.
- Examples: Sometimes prior knowledge is correct but limited (e.g., "the Earth's surface looks flat"), while other times it is a misconception (e.g., "plants get food from the soil").
- Your role: Move beyond being a "sage on the stage“ (teacher-centred) — be a "guide from the side" who uncovers students' beginnings and helps them build accurate scientific frameworks.
- Key task: Diagnose where students stand, identify common misconceptions, and plan instruction to reshape ideas.
- Professional knowledge: Awareness of typical student preconceptions and misconceptions is essential for effective science teaching.

How would you respond to this discussion?

Dissolving discussion

A teaspoon of white powder was added to a beaker of water and then stirred.

At first the mixture was white and cloudy.

After a while the mixture turned clear and colourless, with a layer of white powder at the bottom.

Some children talk about what happened.

Scarlett

The mixture is not coloured so the powder must be soluble.

Ahmed

The white powder was still there at the end, so it must be insoluble.

Chantelle

It turned cloudy, so the powder must be insoluble.

Liam

At the end it was clear again so the powder must be soluble.

New EEF guidance report published: Improving Secondary Science | EEF

The EEF's "Improving Secondary Science" report stresses that students arrive with preconceptions - ideas shaped by experience and prior instruction - which can either support or hinder new learning.

Unaddressed preconceptions that conflict with accepted science can become misconceptions, impeding progress unless specifically diagnosed and tackled by teachers.

Recommendations for teachers

- Build on what pupils bring: The first recommendation calls on teachers to elicit and address students' existing ideas, using classroom dialogue, diagnostic questions, and formative assessment.
- Diagnose and challenge: Teachers should actively uncover common misconceptions, then design lessons that provide evidence to model and correct them.
- Allow time: Transforming misconceptions requires more than a quick fix; teachers must allow enough time for conceptual change and provide compelling counter-evidence.
- Plan purposefully: Incorporate knowledge of typical preconceptions (e.g., "air fills the space between gas particles," "plants get food from soil") to inform teaching strategies.

Threshold concepts

- Threshold concepts are central ideas that, once understood, change how a student sees their subject. They are transformative, irreversible, integrative, bounded, and often troublesome.
- Troublesome knowledge: Threshold concepts are frequently "troublesome" because they challenge intuitive beliefs and prior knowledge—these intuitive beliefs are often the source of common misconceptions in science (e.g., “heavy objects fall faster than light ones” or “plants get food from soil”).
- Liminal state: When grappling with a threshold concept, students often get stuck in a "liminal state" where they may mimic understanding but actually hold misconceptions or incomplete knowledge.

Implications for science teaching

- Misconceptions often cluster around threshold concepts because new learning requires students to "unlearn" ingrained, familiar, but incorrect ideas.
- Addressing threshold concepts directly in teaching is essential to help students make transformative leaps and dissolve persistent misconceptions.
- Example: In physics, the concept of "force" is a threshold concept because it demands reversing the common misconception that continuous force is needed to keep something moving (contradicting Newton’s First Law).
- Effective teaching involves identifying where threshold concepts and misconceptions overlap, explicitly surfacing and challenging those ideas, and guiding students through the learning transformation required to cross the threshold.

Developing pupils' thinking

- Refutation texts
- Cognitively challenging demos
- Diagnostic questions eg BEST/ low stakes testing
- Concept cartoons
- Class and small group discussion

Concept cartoons

Who is correct and why?

Refutation text

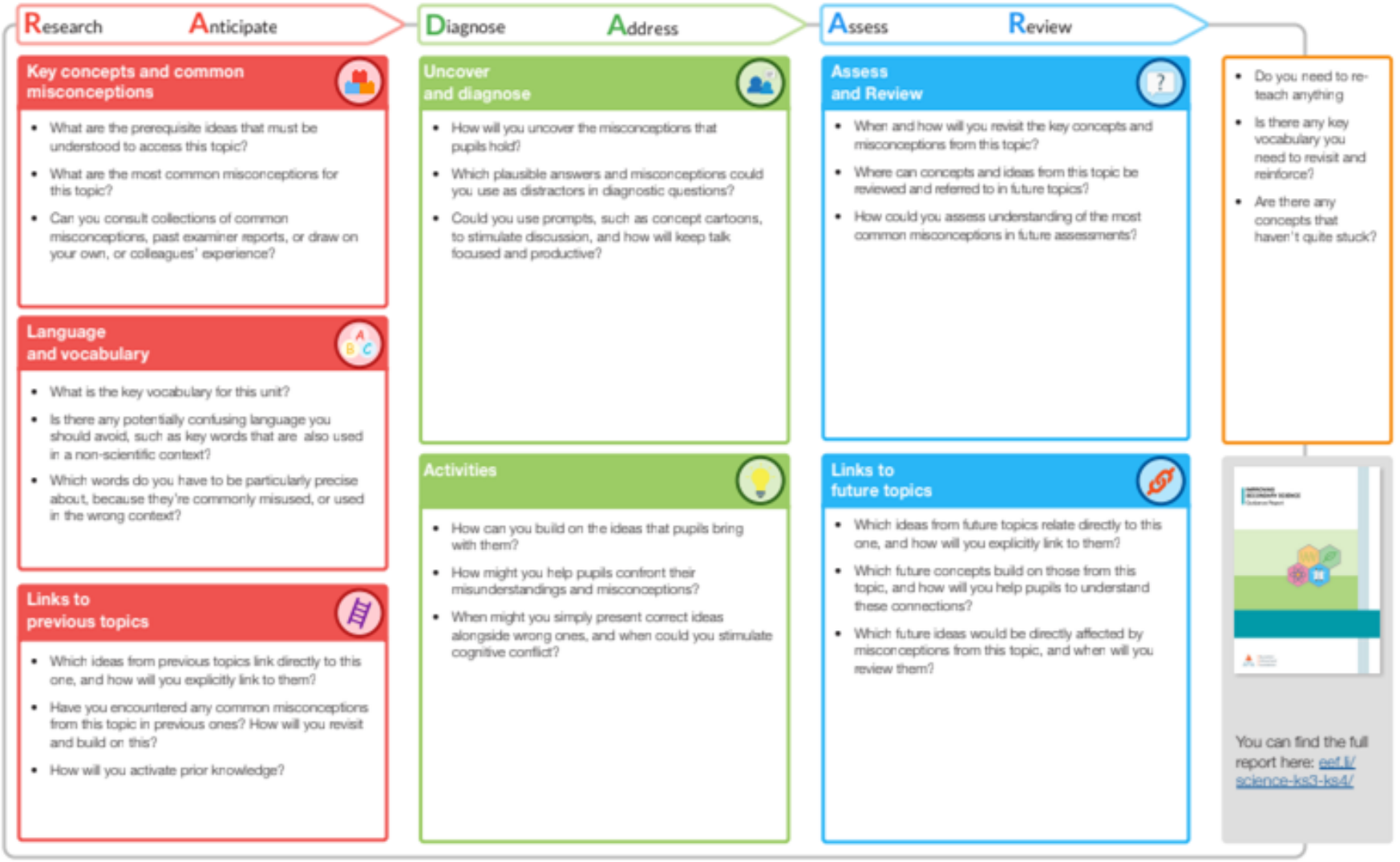
Exploration and teacher-guided discussion of refutation texts have been found to show long term effects

Guzzetti (2000)

1. States the misconception
2. Explicitly states that this is not correct
3. States the accepted viewpoint

Many people think that the color red enrages bulls, but this notion is false (the refutation). The color red does not enrage bulls (the correct answer) because bulls do not see the color red, and, instead, attack because they perceive the matador as a threat (the explanation).

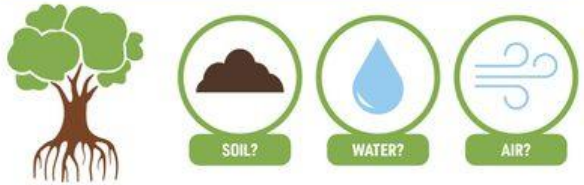
Full report: Improving Secondary Science | EEF



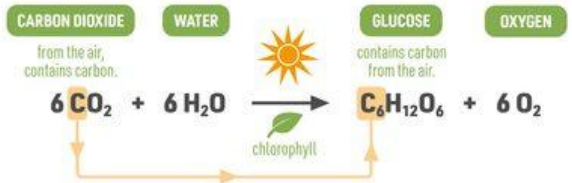
Example RADAAR planning document

- EEF_BEST_infographic_Forces_v4.pdf

WHERE DOES THE MASS OF A TREE COME FROM?



Many people believe the bulk of a tree comes from the soil or the water, but most of its mass is carbon, which comes from carbon dioxide in the air.



Structures like branches and roots are formed using glucose, which is produced from carbon dioxide in the air.

WHY DO MISCONCEPTIONS MATTER?

MRS GREN

They can hinder understanding of more complex ideas
To help children understand ideas about cells, systems and organisms, it's important they appreciate that living organisms may not show all the characteristic processes of life in an obvious way, or all of the time.

They influence how we assimilate new ideas
To help children understand ideas about how and why things react, and how mass is conserved, they need to understand that substances don't simply disappear when they burn, and that air is a substance with mass.

FROM LITTLE ACORNS...

HOW DO BIG OAK TREES GROW?

COMMON MISCONCEPTIONS

ARE SEEDS LIVING THINGS?

Many children believe:
- Seeds aren't alive, or they're only alive once they are planted.
- Trees aren't alive because they don't move around on their own.
- Things like fire and clouds are alive because they appear to be mobile and change shape.

DOES A TREE BREATHE?

Many children believe:
- Plants 'breathe' in reverse, inhaling carbon dioxide and exhaling oxygen.
- Respiration is the same as breathing.
- Plants carry out photosynthesis but only animals carry out respiration.

WHERE DOES WOOD GO WHEN IT BURNS?

Many children believe:
- Air is 'empty' or is just a single gas.
- When wood burns, part of it disappears and no longer exists.
- Wood is more dense than water.

PLANNING AROUND MISCONCEPTIONS (RADAAR)

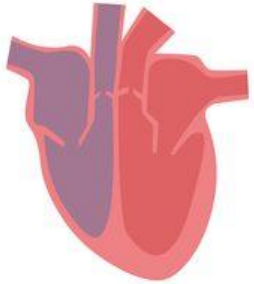
RESEARCH ANTICIPATE — Consider common misconceptions before you teach.

DIAGNOSE ADDRESS — Uncover misunderstandings and build on the ideas that children bring with them.

ASSESS REVIEW — Revisit key ideas and make links with other topics.

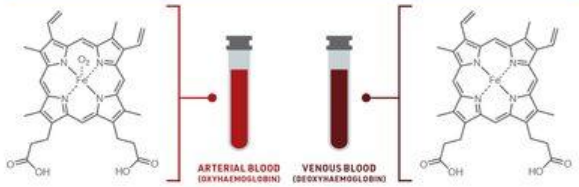
Education Endowment Foundation

WHY ARE OUR VEINS BLUE?



IS IT JUST THE QUEEN WHO HAS BLUE BLOOD?

WHAT COLOUR IS DEOXYGENATED BLOOD?



Many people think that the deoxygenated blood in our veins is blue, and this misconception can be reinforced by textbook depictions of red/blue hearts and circulatory systems. The blood is actually deep red, but our veins look blue due to the scattering of light by the skin.

HOW DO MISCONCEPTIONS ARISE?

We form ideas based on everyday experience
"The sun goes around the Earth, causing day and night."

We have an incomplete understanding
"Giraffes have long necks because their ancestors stretched to reach leaves in trees."

We talk about things anthropomorphically
For example, "atoms want a full outer shell".

Something seems logical
"Copper looks red, so copper atoms are red."

We depict things in a certain way
For example, diagrams with blue-coloured blood.

Everyday words with a specific scientific meaning
For example, the terms weight, mass, work and field.

Common expressions
"I've completely run out of energy!"

COMMON MISCONCEPTIONS

WHERE IS THE HEART LOCATED?

Many children believe:
- Your whole heart is found solely on the left-hand side of your chest.
- The heart pumps air around the body.
- Our bodies are hollow, and blood sloshes around inside them.

HOW DO WE BREATHE?

Many children believe:
- We breathe in **only** oxygen and breathe out **only** carbon dioxide.
- Air goes from our lungs to our heart, which then pumps it around the body.
- Respiration is another word for breathing.

IS ANYTHING LIGHTER THAN AIR?

Many children believe:
- Air doesn't weigh anything.
- A party balloon is lighter when it's full of air than before it's inflated.
- When water boils the bubbles you see are filled with air.

PLANNING AROUND MISCONCEPTIONS (RADAAR)

RESEARCH
ANTICIPATE

Consider common misconceptions before you teach.

DIAGNOSE
ADDRESS

Uncover misunderstandings and build on the ideas that children bring with them.

ASSESS
REVIEW

Revisit key ideas and make links with other topics.

Education Endowment Foundation

References

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Places to go for further info

https://www.stem.org.uk/best-evidence-science-teaching

- STEM Learning Understanding misconceptions https://www.stem.org.uk/resources/elibrary/resource/31725/ understanding-misconceptions

The Royal Society of Chemistry's Learn Chemistry site http://www.rsc.org/learn-chemistry

The Institute of Physics Supporting Physics Teaching site https://spark.iop.org/misconceptions#gref

AAAS Project 2061 http://assessment.aaas.org/topics